NEW CRANIAL ELEMENTS OF A GIANT VARANID FROM QUEENSLAND

R. E. MOLNAR

Molnar, R.E. 1990 09 20: New cranial elements of a giant varanid from Queensland. *Memoirs of the Queensland Museum* 29(2): 437-444. Brisbane. ISSN 0079-8835.

Two massive varanid frontals and matching parietal from the eastern Darling Downs (Queensland) Pleistocene derive from a large varanid, probably *Megalania prisca* . The frontal is characterised by a sagittal crest and low ornamentation on the dorsal surface. The parietal has relatively longer lateral and supratemporal processes than in modern varanids, and a relatively smaller area roofing the braincase. Confluent contacts on the frontal for the prefrontal and postfrontal-postorbital and the encroachment of the supratemporal fossa onto the dorsal surface of the parietal suggest that *M. prisca* was a more derived varanid than any now existing in Australia. The frontal appears quite thick and the endocranial cavity small; these both are probably allometric effects. ☐ *Queensland, Australia, Pleistocene, Varanidae, Megalania, sagittal crest*

R. E. Molnar, Queensland Museum, PO Box 300, South Brisbane, Queensland 4101, Australia; 19 December, 1988.

The giant varanid, *Megalania prisca* (Owen, 1859), is among the most distinctive Australian fossil tetrapods, as well as the largest known terrestrial lepidosaur. It is known from the remains of one skeleton, or possibly two, (Rich, 1985) from the eastern Darling Downs of Queensland, and isolated remains from there and other localities in the eastern half of Australia (Lydekker, 1888; Hecht, 1975). Fossils of *M. prisca* are known only from the Pleistocene. Smaller vertebrae attributed to *Megalania* sp. are known from the Pliocene of Chinchilla, western Darling Downs, Queensland (Hecht, 1975). Recently discovered or recognised material sheds new light, and raises new questions, regarding this animal. The material described here suggests that the skull of *M. prisca* was unusual in its construction.

Specimen numbers prefixed with 'J' or 'F' are held in the Queensland Museum, that prefixed with 'V' in the Ian Sobbe collection and that prefixed by 'BMNH' in the British Museum (Natural History).

DESCRIPTION

In about 1984, Mr Ian Sobbe recovered an unusual bone (F16783) from the Pleistocene deposits at Pearson's Locality, King Creek, eastern Darling Downs, Queensland. In August of 1985 a second, worn specimen (V0033), was recovered, also by Mr Sobbe, from the 'Sutton Bed', King Creek west of Clifton. Both elements are left frontals, approximately equal in size (Table 1). During preparation of this paper, Mr Sobbe donated a large lacertilian right parietal (F16792), collected from King Creek about ten years ago.

In form the frontals are basically like those of *Varanus salvadorii* (Figs 1,2). In dorsal view the element resembles a reversed L, the stem representing the body of the frontal and the lower bar, the lateral process that contacts the fused postfrontal-postorbital distally and the parietal posteriorly. The nasal contact is like that of *Varanus varius*, with the dorsal surface of the frontal projecting anteriorly along the midline. This would give the frontonasal contact a V-shape, with the apex anteriorly directed. A shallow horizontal flange dorsally limits the prefrontal contact. there is no such flange in either *V. salvadorii* or *V. varius*. The lateral process of the frontal is anteroposteriorly nar-

	F 16783	V0033
Midline length	89.2	74.3
Maximum length	93.0	85.6
Maximum width	57.2	48.5
Minimum width at orbit	25.4	25.6
Maximum thickness	25.2	19.8

TABLE 1. Giant varanid frontals (mm).

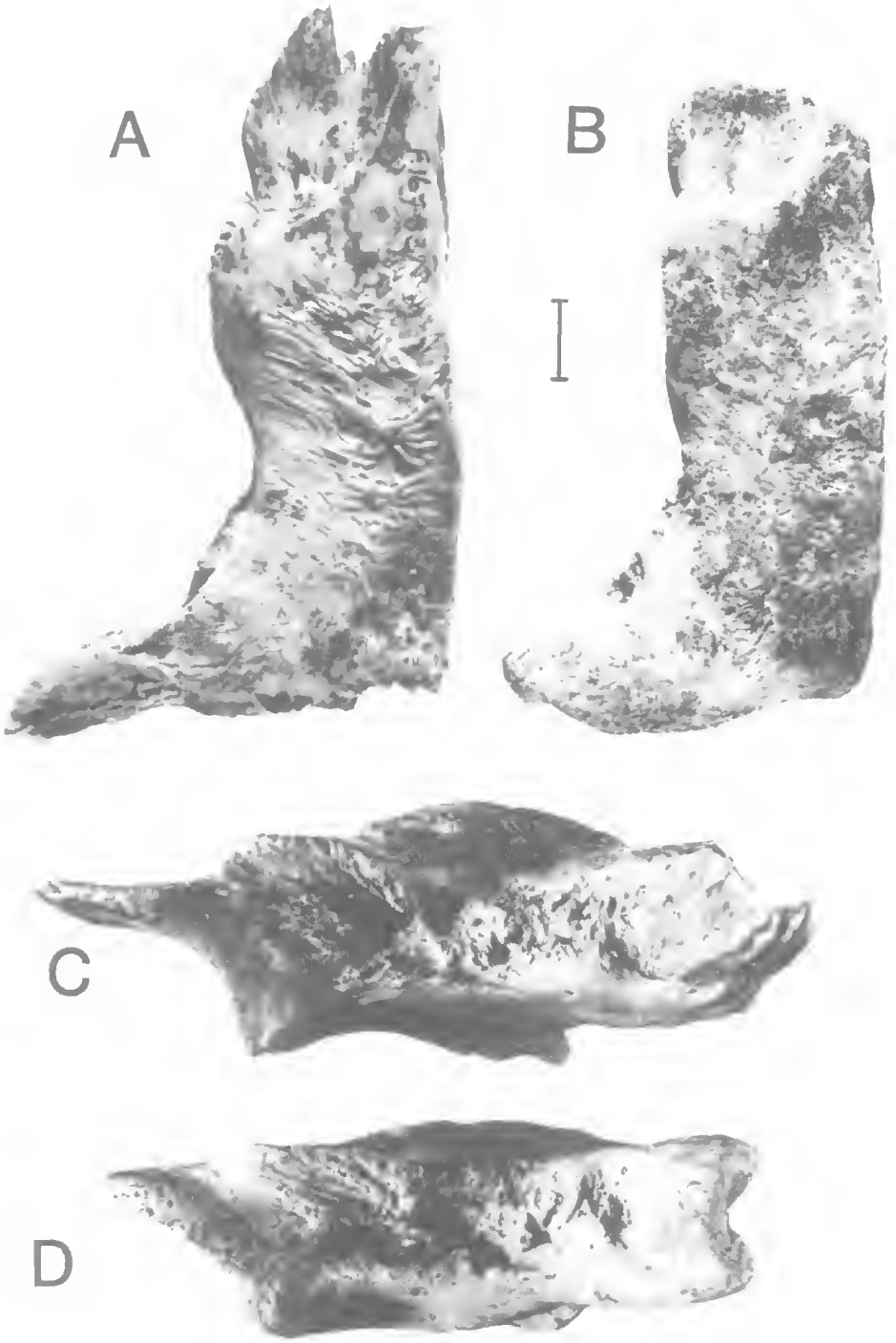

FIG. 1. Left frontals of a large varanid, probably *Megalania prisca* . Unworn frontal (F16783) in dorsal (A) and lateral (C) views. Worn frontal (V0033) in dorsal (B) and lateral (D) views. Scale bar 1cm.

rower, relative to its length, than in the modern species examined (in addition to those noted, *Varanus gouldii* and *Varanus mertensi* were seen). The contact surface for the prefrontal meets that for the postfrontal-postorbital, with no indication of a free orbital margin on the frontal, as there is in modern varanid skulls. F16783 is shorter than the frontal of *V. salvadorii*, more similar in its proportions to that of *V. varius*. However the orbital emargination is placed relatively further back. Ventrally, the frontals are similar in form to those of the modern species. The subolfactory processes are well developed and extend to the midline, hence would be in contact medially. A small foramen penetrates the processes along the midline contact.

The Pleistocene frontals differ from those of modern varanids in three particulars. A distinct sagittal crest is present (Fig. 1C), which terminates posteriorly in front of the parietal contact. This indicates that the crest was limited to the frontal. Lateral to the crest the dorsal face of the frontal is ornamented with low, rounded, mostly parallel ridges (Fig. 1A). Low parallel ridges are often found on vertebrae of *M. prisca*, abutting articular surfaces, but I know of no other varanid with such ornament or, for that matter, any other reptile. However, a low dorsal ridge at the frontal symphysis is apparent in the skulls of several varanids, including *Varanus indicus* (J11017 and J11018), *Varanus spencerii* (J42022 and J47915), *Varanus tristis* (J50726) and *V. varius* (J15361, J16156 and J47065). It is absent in *V. gouldii* (J16135) and *V. mertensi* (J46280). Finally, and most obviously, the King Creek frontal is massive. At the parietal contact the depth of the frontal is 1/4 its midline length; in *V. salvadorii* this ratio is less than 1/10.

The parietal (F16792) is worn, although less than V0033. However the anterior suture pattern is lost. It is a crescentic element (Fig. 2). Apparently both parietals were fused medially, as in modern varanids, but this specimen is broken along the midline. Anteriorly the lateral process projects perpendicular to the longitudinal axis, and posteriorly a longer supratemporal process projects posterolaterally at an angle of 35 degrees to the longitudinal axis. In proportions the parietal is basically similar to those of *V. salvadorii* and *V. varius*, but differs in having a proportionately shorter body. In conjunction with this the supratemporal process of the parietal, which distally contacts the paroccipital process, is relatively longer. At the anterior termination of the mediolaterally compressed supratemporal process a prominent horizontal pit penetrates the body of the parietal. Such a pit is also present in at least *V. varius*.

Although in form basically similar to those of modern varanids, this parietal differs in seven points. A large parietal foramen is present, 1cm in diameter, but set less than 1cm back from the frontal contact. Thus it is more anterior than in the modern varanids seen. The supratemporal process is horizontal and not declined posteriorly as in living varanids. The dorsal margin of this process is distinctly elevated from the dorsal face of the body. This, together with the extension of the supratemporal fenestra over the top of the parietal to the midline, suggests powerful development of the jaw adductors. Correlated with these differences, the flat dorsal face of the parietal extends posteriorly from the frontal contact only to the parietal foramen, unlike the modern varanids available where this surface extends from frontal margin to occipital face. The mediolaterally compressed supratemporal process bears a distinct medial shelf along its entire length but less prominent distally. Such a shelf was not seen on any of the modern varanid material available. Ventrally the area of the parietal roofing the endocranial cavity is strongly reduced compared to the condition in *V. varius* (J47065) and *V. salvadorii* (J14498). The linear dimensions of the endocranial roof are twice those of J47065 (*V. varius*), but the lengths of the lateral and supratemporal processes are three to four times those of that specimen. This reduction of amount of the parietal forming the endocranial roof is reflected in the extension of the parietal laterally beyond the lateral walls of the braincase.

The broken face of the parietal shows a depth of 2.5cm of which the top 0.5cm is compact bone and most of the remainder is spongy bone. A thin (0.2cm) layer of compact bone forms the ventral surface.

Scaling

The large size of the King Creek varanid cranial material leads to questions of its scaling. This is relevant to the following taxonomic discussion and interesting in its own right. Two issues will be raised: whether the apparent thickness of the frontals results only from their large size and the relative size of the endocranial cavity.

Could the appearance of thickness of the frontals and parietal from King Creek simply be the result of scaling? McMahon's elastic scaling

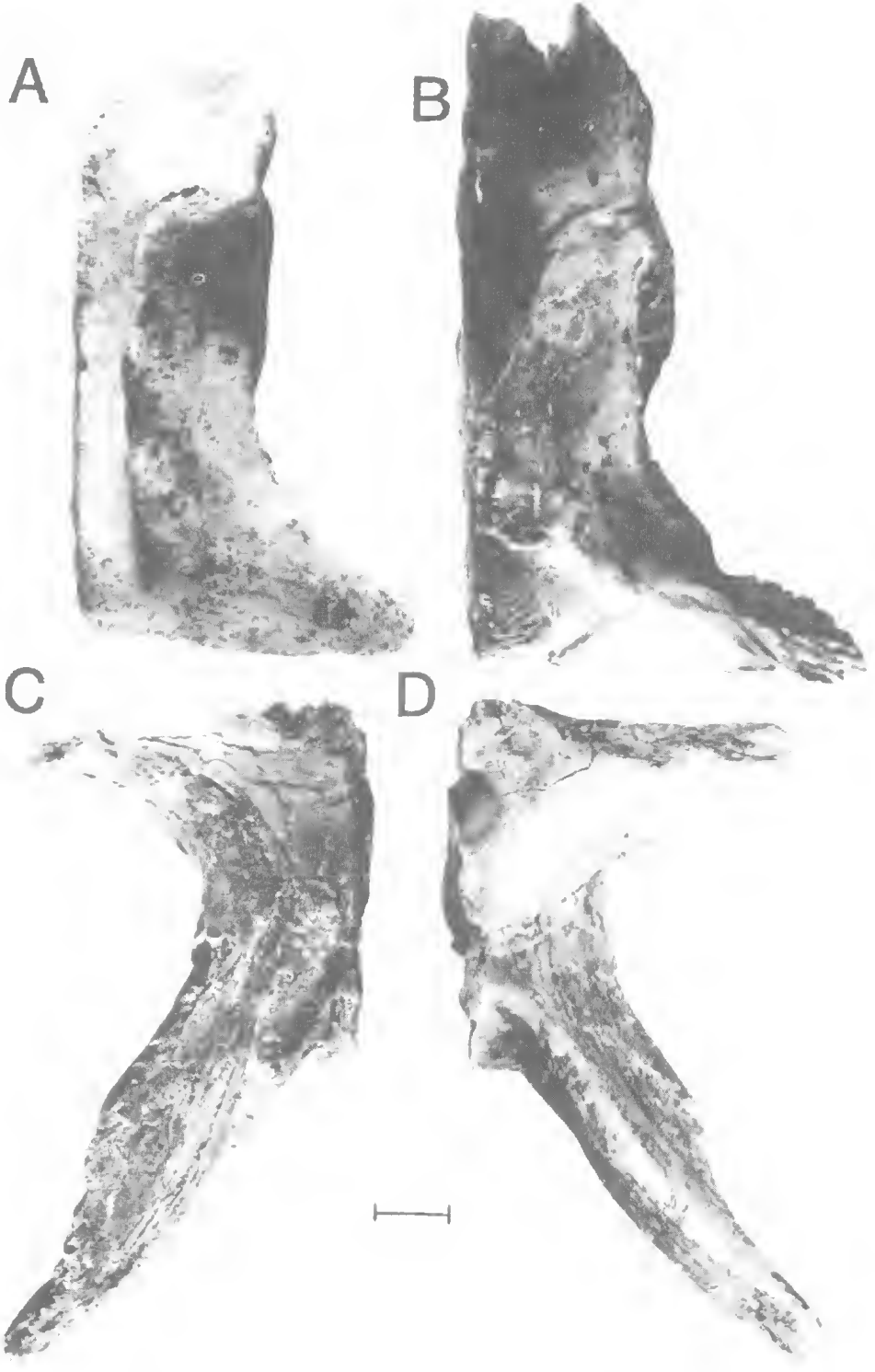

FIG. 2. Left frontals and right parietal of a large varanid, probably *Megalania prisca* . Worn frontal (V0033)

(McMahon, 1973; McMahon and Bonner, 1983), for which there is some evidence when applied to the anatomical analogues of columns (Hamley, 1990; McMahon, 1975), recognises that transverse linear dimensions scale as the 3/2 power of longitudinal linear dimensions. McMahon assumes that the orthogonal transverse dimensions will be equal, that is $D^2 = L^3$ where D is the transverse dimension and L the length. However if the two orthogonal transverse dimensions were not equal, as is here the case, then it would follow from the derivation that $D1 \times D2 = L^3$. In this case if D1 is the width of the frontal and D2 its thickness, we wish to find the value of D2 expected from knowing L and D1, if the large frontal were to have the same resistance to bending as the frontals of smaller modern varanids (here *V. salvadorii* and *V. varius*). This analysis treats the frontals as a plate principally resisting bending stresses imposed in biting, and transmitting the forces then impressed to the parietal and occipital regions of the skull. It also assumes that the frontals can be regarded as simple plates with resistance to bending proportional only to the cross-sectional area. It ignores any possible role in stiffening the frontals of the subolfactory processes, which in varanids make the posterior part of the frontals into a flattened tube. It also ignores the role of the sagittal crest of the King Creek frontals. However these effects will be ignored here for two reasons, first they are technically difficult to treat, and second both considerations would act to increase the resistance to bending of the frontals. Thus consideration of both factors would tend to decrease the estimate of thickness for scaled up frontals. I wish to determine if the King Creek frontals are thicker than expected from arguments of scaling and hence wish to err (if at all) on the side of estimating too thick rather than too thin.

Working with the dimensions of the two available skulls, J14498 (*V. salvadorii*) and J47065 (*V. varius*), it appears that the thickness of the King Creek frontals is such as would be predicted from elastic scaling. Scaling up the skull of *V. salvadorii* would give a frontal about 20 mm thick, which is close to the thickness of the F16783 (19.8 mm), while scaling up that of *V. varius* would predict frontals even thicker, about 45 mm thick. In view of the approximations used in making these calculations, this is viewed as reasonable agreement (i.e. within one order of magnitude), providing no evidence that the frontals from King Creek are unusually thick.

For purposes of an order of magnitude calculation the endocranial cast of a varanid may be approximated by a six-faced irregular but bilaterally symmetric polyhedron that approximates the endocranial cavity. The ventral surface of the parietals forms the upper face of the polyhedron. This polyhedron was defined from examination of the figures 10, 17 and 18 of Starck (1979) and of a skull of *V. varius* (J1656) that retains some of the soft connective tissue walling the endocranial cavity. The figures of Starck (1979) indicate that in *V. salvator* at least virtually all of the brain is included within this volume, although not filling it. The similarity in form of the parietals of *V. varius* to that from King Creek, suggests that this polyhedron may be used to approximate the endocranial cavity of that form as well. Because the same polyhedron is used in both instances, if the ratio of the areas of the corresponding face of each of the two polyhedra is known, the ratio of the volumes can be calculated.

The endocranial surface of the parietals of F16792 is about 5 times greater than that of *V. varius* (J47065). Using the relationship that volume is proportional to the 3/2 power of area, this gives a ratio of volumes of about 11 to 1. This result gives no indication that the endocranial cavity of the King Creek varanid was relatively smaller than in the modern *V. varius* in spite of the fact that relatively less of the ventral face of the parietal roofs the endocranial cavity in the fossil form than in the living one. In modern varanids the brain is substantially smaller than the endocranial cavity and so does not closely conform to the endocranial surfaces (Starck, 1979, figs 17 and 18). Thus no inferences regarding relative brain size will be essayed here.

TAXONOMIC IDENTIFICATION

Varanoid frontals are characterised by the structure of the subolfactory processes (Pregill et al., 1986), which are well developed and come in contact medially. Thus the King Creek frontals are varanoid. Pregill et al. (1986) cite a mediolaterally compressed supratemporal process of the parietal as characteristic of varanids, hence this parietal derives from a varanid.

The parietal matches in the size the two frontals, suggesting that both elements derive from the same species. Unfortunately the anterior suture pattern on the parietal has been worn, so

direct comparison of their forms is not possible. However, some similarity is evident. The parietal contact face of the frontal is stepped, its medial centimetre situated slightly forward of the lateral portion. The anterior face of the parietal shows a corresponding step, with its medial centimetre set slightly forward. The dorsoventral thickness of the lateral process (2.1cm) matches that of the frontal (2.0cm), so that the two elements could have derived from the same individual. The parietal is also consistent in size with the occipital segment of Owen (1880), although that comes from Gowrie, not King Creek. The similar thickness and form of the frontal-parietal contact indicates that the frontals and parietal probably derive from the same species.

Further evidence for common derivation could be given if the parietal had a similar pattern of ornament. Unfortunately there is no indication on the dorsal face of the parietal of the unique sculpture or the sagittal crest seen on the frontal. Because the dorsal face of the parietal has been worn and the sculpture of the frontal is very subdued at its posterior margin, sculpture may have been present and lost from wear. A sagittal crest, however, should have been sufficiently marked to have survived this degree of wear, were any crest present on the parietal.

Presumably this material pertains to *Megalania prisca*. The holotype of *M. prisca* consists of two and half dorsal vertebrae (BMNH 32908a, 32908b and 32908c: Lydekker, 1888), and so reference to this species must depend on comparison with associated material. No frontals or parietals of *M. prisca* were previously known (Rich, 1985, figure on p. 154). However both King Creek frontals were found in association with material of *M. prisca*, vertebrae and teeth at Pearson's locality and vertebrae and a tibia at Sutton's bed. But much other tetrapod material has also been found at these localities, so no firm conclusion may be drawn from this. However *M. prisca* is the only large varanid known from Pleistocene Australia, and since these skull roof elements derive from a large varanid, reference to *M. prisca* is reasonable.

Further conclusions may be drawn regarding the evolutionary position of the beast from which these elements derived. A close approach of the prefrontal to the postfrontal above the orbit is a derived feature (Pregill et al., 1986). Thus confluent contact surfaces for the prefrontal and postfrontal-postorbital is a derived feature. So these frontals represent a more derived condition than any surviving Australian varanids examined. The parietal appears less derived, in that it retains the parietal foramen (Pregill et al., 1986), and a large one at that. However I would suggest, by analogy with the evolution of the cranial roof in large theropod dinosaurs (Walker, 1964), that reduction of the flat dorsal surface of the parietal by encroachment of the supratemporal fenestrae is also a derived feature in varanoids. This suggests that *Megalania* represents a more derived varanid than now exists in Australia.

DISCUSSION WITH SPECULATIONS

The frontals and parietal from King Creek appear obviously thicker than the maxillae and dentary attributed to *Megalania prisca* . Either the skull roof was considerably thicker than the trophic apparatus, or the roof elements derive from an individual larger than those from which the jaws are known, or there was variation, such as sexual dimorphism, in thickness of the skull elements.

A dentary, F6562, from an animal presumably approximately equal in size to that from which the cranial roof elements derive, is at the base of the teeth (where it is thickest) only 60% as thick as the frontal F16783. A maxilla (F12370), also apparently from an animal of this size, is equally thin compared to the frontal. This is not the case in the skulls of living varanids, where the frontal and dentary are approximately equally thick. The only other amniotes known to me with the skull roof significantly more massive than the trophic apparatus are the herbivorous pachycephalosaurian dinosaurs (Maryanska and Osmolska, 1974). These are quite different in cranial form. The tooth form of *M. prisca* implies that it was most likely either a predator or scavenger. In neither case is the braincase expected to be more robust than the trophic apparatus: such construction is unknown among living predators and scavengers.

The frontal and parietal appear to be approximately of the size expected to match the known maxillae and dentary, to judge from comparison with living varanids. Unless its cranial proportions were very different from modern varanids they would not derive from an individual 30% larger than those from which the jaws come. So the possibility that they derive from individuals of different sizes seems remote.

Possibly one sex, presumably the male, had a more robust skull, or at least skull roof, than the other. There is at present no way of testing this

possibility. Sexual dimorphism is unknown in living varanids, but the environmental circumstances of *Megalania* were doubtless different and sexual dimorphism is known in some mammalian top carnivores, e.g. lions.

The frontal crest suggests habits different from those of living varanids. It may have been a weapon, or display (species recognition) structure. *M. prisca* would presumably have been a top carnivore of the Australian Pleistocene (cf. Rich, 1985) and thus, at least in some respects, analogous to the large theropod dinosaurs of the Mesozoic. Large theropods bore cranial ornament, usually horns or crests (Molnar, 1977; Kurzanov, 1976; Welles, 1984; Bonaparte, 1985), thus it is not unreasonable to suggest that *M. prisca* too might have had cranial ornament. The frontal crest may have been used in head to head shoving contests, as among the marine iguana *Amblyrhynchus cristatus* (Carpenter, 1978). Living varanids are not known to engage in such contests (Stamps, 1977; Carpenter, 1978), but the circumstances of the life of *M. prisca*, as a large terrestrial top carnivore were unlike those of modern varanids.

A different speculative significance of the crest has also been suggested. It is well known that aquatic lizards (including some varanids) usually show lateral compression of the tail and sometimes the trunk. Furthermore many show some development of a dorsal ridge or crest along the back and tail, as in *Hydrosaurus amboinensis* (although rarely so prominent). In some species of *Basiliscus* these crests are complemented by a crest on the skull roof. Possibly the sagittal crest of the King Creek frontal indicates aquatic or amphibious habits. A cranial crest is found in some arboreal lizards, such as *Corythophanes*. We seem safe in presuming, however, that the giant King Creek varanid was not arboreal.

If the King Creek varanid was amphibious or aquatic, one might expect that crocodiles would have been rare in its habitat. Indeed, crocodile remains are rare (Pearson's locality) or absent (Sutton's bed) from the localities and levels at which the frontals were found (Sobbe, pers. comm., 1988; also cf. Bartholomai, 1976). This suggests that competition for the niche of a large aquatic predator would have been weak or absent. It also suggests that predation on a large aquatic lizard would have been weak or absent.

CONCLUSIONS

Two frontals and a parietal from King Creek, eastern Darling Downs, Queensland, indicate the presence of a giant varanid. This form, presumably *Megalania* , was more derived than living varanids in two features: the contact of the articular surfaces for prefrontal and postfrontal-postorbital and the encroachment of the supratemporal fenestra over the top of the parietals. Both the appearance of unusually thick frontals and of a relatively small endocranial cavity seem to result from scaling effects.

ACKNOWLEDGEMENTS

The persistence and acute eye of Mr Ian Sobbe in finding the cranial material and his kindness in donating it made this paper possible. Two of the speculations discussed in above - sexual dimorphism and aquatic habitus - were suggested by Tony Thulborn and Greg Czechura, respectively. They are not, of course, responsible for my treatment of their suggestions. Valuable assistance was also given by Drs M. Borsuk-Bialynicka (Warsaw), R. Estes and G. K. Pregill (both in San Diego).

LITERATURE CITED

BARTHOLOMAI, A. 1976. Notes on the fossiliferous Pleistocene fluviatile deposits of the eastern Darling Downs. Bull. Miner. Resourc. Geol. Geophys. Aust. 166: 153- 4.

BONAPARTE, J. F. 1985. A horned Cretaceous carnosaur from Patagonia. Nat. Geog. Research 1: 149-51.

CARPENTER, C. C. 1978. Ritualistic social behaviors in lizards. pp. 253-67. *In* Greenberg, N. and MacLean, P. D. (eds), 'Behavior and Neurology of Lizards.' (National Institute of Mental Health: Rockville).

HAMLEY, T. 1990. Functions of the tail in bipedalism of lizards and dinosaurs. Mem. Qd Mus. 28: 153-8.

HECHT, M. K. 1975. The morphology and relationships of the largest known terrestrial lizard, *Megalania prisca* Owen, from the Pleistocene of Australia. Proc. R. Soc. Vict. 87: 239-49.

KURZANOV, S. M. 1976. Novie pozdnemelovoi karnozavr iz Nogon-Tsava, Mongoliia. Sovmest. Sovet.-Mongol. Paleont.Eksped., Trudy 3: 93-104.

LYDEKKER, R. 1888. 'Catalogue of the Fossil Reptilia and Amphibia in the British Museum

(Natural History), Cromwell Road, S.W. Part 1.' (British Museum: London). 309pp.

MARYANSKA, T. AND OSMOLSKA, H. 1974. Pachycephalosauria, a new suborder of ornithischian dinosaurs. Palaeont. pol. 30: 45-102.

McMAHON, T. A. 1973. Size and shape in biology. Science 179: 1201-4.

1975. Allometry and biomechanics: limb bones in adult ungulates. Amer. Nat. 109: 547-63.

McMAHON, T. A. AND BONNER, J. T. 1983. 'On Size and Life.' (Scientific American Library: New York). 255pp.

MOLNAR, R. E. 1977. Analogies in the evolution of combat and display structures in ornithopods and ungulates. Evol. Theory 3: 165-90.

OWEN, R. 1859. Description of some remains of a gigantic land-lizard (*Megalania prisca* *, Owen) from Australia. Phil. Trans. R. Soc. London 149: 43-8.

1880. Description of some remains of the gigantic land-lizard (*Megalania prisca*), from Australia.- Part II. Phil. Trans. R. Soc. London 171: 1037-50.

PREGILL, G. K., GAUTHIER, J. A. AND GREENE, H. W. 1986. The evolution of helodermatid squamates, with description of a new taxon and an overview of Varanoidea. Trans. San Diego Soc. Nat. Hist. 21: 167-202.

RICH, T.H. 1985. *Megalania prisca* the giant goanna. pp. 152-5. *In* Rich, P. V. and van Tets, G. F. (eds), 'Kadimakara'. (Pioneer Design: Melbourne).

STAMPS, J. A. 1977. Social behavior and spacing patterns in lizards. pp. 265-334. *In* Gans, C. and Tinkle, D. W. (eds), 'Biology of the Reptilia, 7, Ecology and Behaviour A'. (Academic Press: London).

STARCK, D. 1979. Cranio-cerebral relations in recent reptiles. pp. 1-38. *In* Gans, C., Northcutt, R. G. and Ulinski, P. (eds), 'Biology of the Reptilia. Vol. 9, Neurology A.' (Academic Press: London).

WALKER, A. D. 1964. Triassic reptiles from the Elgin area: *Ornithosuchus* and the origin of carnosaurs. Phil. Trans. R. Soc. London, B 248: 53-134.

WELLES, S. P. 1984. *Dilophosaurus wetherilli* (Dinosauria, Theropoda) osteology and comparisons. Palaeontographica A 185: 85-180.